Food Policy 44 (2014) 36–46

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

# Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns

C. van Dooren [a,*], Mari Marinussen [b], Hans Blonk [b], Harry Aiking [c], Pier Vellinga [c]

[a] Netherlands Nutrition Centre (Voedingscentrum), P.O. Box 85700, 2508 CK The Hague, The Netherlands
[b] Blonk Consultants, Gravin Beatrixstraat 34, 2805 PJ Gouda, The Netherlands
[c] Institute for Environmental Studies, VU University, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands

ARTICLE INFO

*Article history:*
Received 27 February 2013
Received in revised form 29 August 2013
Accepted 4 November 2013

*Keywords:*
Sustainable diet
Dietary guidelines
Mediterranean diet
Climate change
Land-use
Health score

ABSTRACT

The objective of this study was to explore the synergies between nutritionally healthy and ecologically sustainable diets. The aim was to explore the possibilities for future integrated dietary guidelines that support consumers to make informed dietary choices based on both ecological and nutritional values. We developed a score system for health and sustainability. Subsequently, we tested six different diets: current average Dutch, official 'recommended' Dutch, semi-vegetarian, vegetarian, vegan and Mediterranean. For the sustainability rating, we used the Life Cycle Assessment, measuring the impacts on greenhouse gas emissions (GHG) and land use (LU). For the health rating, we used ten nutritional indicators. By comparing the overall scores we found that the consumption of meat, dairy products, extras, such as snacks, sweets, pastries, and beverages, in that order, are largely responsible for low sustainability scores. Simultaneously, these food groups contribute to low health scores. We developed a matrix that illustrates that the health and sustainability scores of all six diets go largely hand in hand. Fig. 1 provides a visualisation of the position of the six diets in the full health and sustainability spectrum. This matrix with scores can be considered a first step in the development of a tool to measure both sustainability and health issues of specific food patterns. In selecting the diets, we examined two directions: health focus diets and the animal protein reduction diets. The Mediterranean diet is generally the health focus option with a high sustainability score. We conclude that guidelines oriented in between the two directions (i.e., semi- and pesco-vegetarian) are the option with the optimal synergy between health and sustainability.
© 2013 Elsevier Ltd. All rights reserved.

## Introduction

### *Societal food concerns: health and sustainability*

Dietary guidelines issued by governments, health councils, and nutrition institutes are mainly focused on nutrition and health issues in response to upcoming Western, food-related lifestyle diseases. The present study refers to the WHO recommendations (WHO, 2003) for nutritional adequacy and healthy diets. These guidelines, together with national recommendations like the British guidelines (BNF, 2007), the new Dietary Guidelines for Americans (USDA, 2010), and the Dutch Dietary Guidelines (DDG; Health Council, 2006) support consumers to make healthy, informed choices. Such guidelines, however, do not address another major societal concern: the quality of the natural environment and sustainability issues.

Current trends in food production and consumption are considered unsustainable. For example, approximately one-third of human influence on climate change and land use (LU) is related to our diet and the food chain (Dutilh and Kramer, 2000; Tukker et al., 2006; Vringer et al., 2010; Garnett, 2011). This is more than the impacts of leisure, housing or labour. Climate change mitigation policies tend to focus on the energy sector, while the livestock and food sector receives less attention, despite the fact that this sector accounts for 18% of the greenhouse gas (GHG) emissions and 80% of total anthropogenic land use (Stehfest et al., 2009). Land use is the major driver for loss of biodiversity. Although food is a necessity in life, personal diet choice can strongly influence these impacts.

These societal concerns result in a growing interest by policy makers as well as consumers to integrate healthy and environmentally friendly diet recommendations. It is important for governments and institutions to not send conflicting messages to consumers on these issues. Experts have reached a consensus about the notion that *Future dietary guidelines* (are needed) *to be based on ecological (including climatological) as well as nutritional science* (Simopoulos et al., 2011).

* Corresponding author. Tel.: +31 70 306 88 56.
*E-mail addresses:* dooren@voedingscentrum.nl (C. van Dooren), mari@blonkconsultants.nl (M. Marinussen), hans@blonkconsultants.nl (H. Blonk), harry.aiking@vu.nl (H. Aiking), pier.vellinga@vu.nl (P. Vellinga).

0306-9192/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodpol.2013.11.002

The actual diet is related to consumers' personal food choices and behaviour (Hahn, 1988). Research shows that consumers have little awareness of their diets environmental impact, but many would be open to making more sustainable choices if it were easy to do so. Simpler, more user-friendly information and advice about how to make more sustainable choices is therefore necessary (Davies, 2011). The first stage in most behaviour change models is problem recognition: consumers need a sense of urgency and some awareness (Prochaska and DiClemente, 1983; Weinstein et al., 1998). For awareness, consumers need to have knowledge (information) about the problematic character of current unsustainable consumption patterns and the dramatic consequences that will likely result from these patterns. For a sense of urgency, consumers need to be convinced that a shift towards more sustainable consumption is needed in order to accommodate the increasing world population's needs and to prevent environmental damage (Schwinghammer, 2013).

During the last few decades, awareness about 'planetary health' and 'sustainable' diets has increased (Gussow, 1999). It was in 1986 that Joan Dye Gussow formulated her first dietary guidelines for sustainability (Gussow and Clancy, 1986). More recently, the British (Reddy et al., 2009), Swedish (Livsmedelsverket, 2009), German (Gerlach et al., 2009), Finnish (Steering Group, 2010), and Belgian governments (FRDO, 2011) have put together committees to give policy advice on 'sustainable' diets. A growing body of research suggests that if we are to achieve substantial reductions in food-related GHG emissions, then we will have to address not only how we produce and distribute our food but also what we eat (Garnett, 2011). In 2010, the Dutch Ministry of Economic Affairs, Agriculture and Innovation asked the Health Council *An opinion on the latest state of knowledge in 'Sustainable Food Guidelines' and choice options for the selection of food by consumers.* Our study has been set up to provide scientific input to this opinion. The opinion was published in 2011 (Health Council, 2011).

This study is obviously from the perspective of a developed nation where ample dietary variety, food supplies and nutritional advice are available. It aimed to explore the development of integral, practical, and achievable dietary guidelines, based on synergies between health and sustainability. Different European (Baroni et al., 2006; Risku-Norja et al., 2009) and Dutch studies (Elferink, 2009; Gerbens-Leenes, 2006; Kramer et al., 1999) have already quantified the impact of animal protein reduction scenarios on energy consumption, land use, and greenhouse gas emissions. To date, few studies have systematically combined and quantified both the health and sustainability impacts of different diet options. Meanwhile, consumers call for easier choices based on future dietary guidelines.

Obviously, what makes one diet more sustainable than another diet needs to be defined. A definition was recently agreed upon by the FAO (2010a): *Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimising natural and human resources.* This definition combines elements of ecological impact and healthy life. Of course sustainable diets will have to be nutritionally adequate. To develop integral nutritional advice, additional insight is needed into the potential effects of different changes in diet on climate impact, land use, and health gains, and the mutual synergies or conflicts between these elements.

In this paper, we start by selecting six diets representative for a broad range of personal diets. Next, we describe the method we used to rate health aspects and sustainability aspects. In the results section, we present the resulting scores, illustrating a number of synergies between health and sustainability. Finally, we analyse the results in terms of food groups and identify the food groups that contribute most to the final scores. The analysis should be considered a first step in the development of guidelines on food in diets that meet consumers' needs regarding both health and sustainability aspects.

## Theory: development of methodology

In this section, some potential indicators of diets' sustainability and health gains are evaluated.

### *Six diet options selected*

To explore the different options, we selected six diets. In many publications about sustainable food patterns, in addition to the most highly mentioned reduction of meat consumption, 'vegan' and 'Mediterranean' diets are frequently cited as more sustainable options (Baroni et al., 2006; Burlingame and Dernini, 2011; Marlow et al., 2009). This article will investigate these and other options. Six diets were selected by the authors with the aim to illustrate the effect of a wide range of quantities in consumption of animal products, fruits, vegetables, cereals and energy-dense products. These diets were as follows:

1. VCP 1998 – average Dutch consumption: Best available public source is the Dutch National Food Consumption Survey (VCP) 1998 (TNO, 1998). In 2011, the RIVM (National Institute for Public Health and the Environment) published a new survey, but the survey results were not yet available at the time of the present study.
2. DDG – recommended Dutch Dietary Guidelines (Health Council, 2006): These guidelines consist of a few quantitative recommendations for adults based on nutritional adequacy and health gains as mentioned in Section Indicators and health gain score.
3. Semi-vegetarian (50/50): This diet is an average between diets 2 and 4. This option is selected to incorporate a diet which may serve as a compromise between sustainability and palatability to the general public.
4. Traditional vegetarian (ADA, 2009): There are no Dutch data available on the consumption of meat substitutes by vegetarians. In consultation with experts on vegetarianism (staff members of the Dutch Vegetarians Union), we replaced the weekly meat consumption with the following: 4 eggs, 1 portion of pulses (75 g), 250 g nuts, and 3 portions (300 g) of ready-to-eat meat substitutes, such as tofu.
5. Vegan (ADA, 2009): In the vegan diet, milk is replaced by calcium-enriched soy drinks. Protein products are in line with the vegetarian option, but the eggs are replaced by an extra portion of pulses. Vegetable consumption is increased by 200 g, and the vegetables are rich in calcium.
6. Mediterranean: This is a diet lower in meat, high in fish, fruits, and vegetables, with fewer extras, and plant oils instead of animal fats. An excellent, quantitatively defined description of this diet was published by Fidanza and Alberti (2005). Willett (2001) published together with Oldways in 2009 the Mediterranean Diet Pyramid (www.oldwayspt.org). A consensus meeting recently updated the Mediterranean diet pyramid and gave quantification in servings, but without portion sizes (Bach-Faig et al., 2011).

The diets 2–6 (quantified in Table 1) meet the Dutch Dietary Guidelines (Health Council, 2006). The vegetarian and vegan diets are to a high degree comparable to the vegetarian and vegan adaptations of USDA food patterns (USDA, 2010). The latter differ from the Dutch recommendations of more vegetables and fruit (in con-

**Table 1**
Average daily consumption of women in the Netherlands, aged 22–50 years, according to six diet options.

| Cat. | Product group | Diet Unit | 1 Average Dutch | 2 DDG | 3 Traditional vegetarian | 4 Semi-vegetarian | 5 Vegan | 6 Mediterranean |
|---|---|---|---|---|---|---|---|---|
| 1.1 | Vegetables | g | 127 | 200 | 200 | 200 | 400 | 300 |
| | Fresh | g | 82 | 129 | 129 | 129 | 279 | 300 |
| | Other | g | 45 | 71 | 71 | 71 | 121 | 0 |
| 1.2 | Fruit | g | 103 | 200 | 200 | 200 | 200 | 250 |
| 2.1 | Bread | g | 119 | 210 | 210 | 210 | 210 | 210 |
| | Grain products | g | 51 | 65 | 61 | 63 | 53 | 100 |
| | Potatoes | g | 101 | 129 | 117 | 125 | 105 | 25 |
| | Pulses | g | 4 | 6 | 11 | 5.5 | 21 | 75 |
| 2.2 | Grains, potatoes, pulses | g | 156 | 200 | 200 | 200 | 200 | 200 |
| 3.1 | Milk and milk products | g | 332 | 450 | 450 | 450 | 0 | 300 |
| | Soy drink | | | | | | 450 | |
| 3.2 | Cheese | g | 30 | 30 | 30 | 30 | 0 | 15 |
| | Meat, meat products, poultry | g | 102 | 41 | 0 | 22 | 0 | 30 |
| | Fish | g | 9 | 37 | 0 | 19 | 0 | 37 |
| | Eggs | g | 13 | 21 | 29 | 21 | 0 | 29 |
| | Soy products and meat substitutes | g | 2 | 0 | 43 | 20 | 43 | 4 |
| 3.3 | Meat, fish, eggs and meat substitutes | g | 126 | 100 | 71 | 82 | 43 | 100 |
| 4.1 | Oils, fats, sauces | g | 46 | 45 | 45 | 45 | 45 | 45 |
| | Butter | g | 3 | 3 | 0 | 1.5 | 0 | 0 |
| | Other | g | 43 | 42 | 45 | 43.5 | 45 | 45 |
| 5.1 | Drinks, non-alcoholic | ml | 1487 | 1500 | 1500 | 1500 | 1500 | 1500 |
| 6 | Non-basic products | | | | | | | |
| 6.7 | Drinks, alcoholic | ml | 94 | 150 | 150 | 150 | 150 | 150 |
| 6 | Other extra products | kcal | 859 | 300 | 300 | 300 | 300 | 200 |
| | Energy from non-basic products | % | 42% | 15% | 15% | 15% | 15% | 10% |
| | Total energy intake | kcal | 2031 | 2000 | 2000 | 2000 | 2000 | 2000 |

**Table 2**
Health gains and scores of the six diets, based on ten indicators.

| Indicators | | | | | Reference value | | Diets | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cat. | Description | Source | | | | | 1 | 2 | 4 | 3 | 5 | 6 |
| | | WHO | WCRF | RIVM | DHC/WHO (index = 100) | Unit | Average Dutch | DDG | Semi-vegetarian | Traditional vegetarian | Vegan | Mediterranean |
| 1 | Vegetables | * | * | * | 200 | g | 64 | 100 | 100 | 100 | 150 | 150 |
| 2 | Fruits | * | * | * | 200 | g | 52 | 100 | 100 | 100 | 100 | 125 |
| 3 | Total fatty acids | * | * | | 30[**] | en% | 102 | 116 | 122 | 128 | 151 | 132 |
| 4 | Saturated fatty acids | * | | * | 10[**] | en% | 83 | 105 | 109 | 114 | 155 | 131 |
| 5 | Trans fats | * | | * | 1[**] | en% | 140 | 140 | 150 | 150 | 160 | 150 |
| 6 | (free) Sugars | * | * | | 10[**] | en% | 46 | 104 | 104 | 104 | 135 | 124 |
| 7 | Fibre | * | * | | 30 | g | 67 | 99 | 98 | 98 | 113 | 109 |
| 8 | Salt (sodium chloride) | * | * | * | 6[**] | g | 75 | 85 | 93 | 102 | 117 | 95 |
| 9 | (fatty) Fish | * | | * | 37 | g | 24 | 100 | 49 | 0 | 0 | 100 |
| 10 | Energy balance | | * | * | 2000 | kcal | 98 | 100 | 100 | 100 | 100 | 100 |
| | Health score | | | | 100 | | 75 | 105 | 103 | 100 | 118 | 122 |

[**] Upper limits.

trast, including potatoes and juices), more milk but without cheese, and a separate recommendation for nuts and seeds.

If only plant foods are consumed, choices should include foods fortified with vitamin B12, vitamin D, and calcium. Other nutrients of potential concern (without any quantified recommendations) include iron, choline, EPA, and DHA (DGAC, 2010).

### *Indicators and health gain score*

The health benefits of diets are highly complex and under continual debate and they cannot be quantified directly and easily but via the most essential and relevant indicators. Fortunately, different health organisations such as WHO, WCRF (World Cancer Research Fund), RIVM, and the Dutch Health Council (DHC) have been using more or less the same indicators. An overview of these indicators is given in Table 2. These ten nutritional indicators, as defined in this section, are related to different food-related diseases, such as obesity, heart disease and cancer.

For the US Department of Agriculture, Kennedy et al. (1995) developed the Healthy Eating Index to quantify overall diet quality. The Centre for Nutrition Policy and Promotion has been successfully using this index within the US for several years (Kennedy et al., 2008). This index is not directly applicable to Europe due to differences in cultural habits (serving sizes) and nutritional guidelines. Nevertheless, the concept is useful to suggest a related score relevant to the European context. Therefore, we need to first select the most important nutritional indicators related to diet-related diseases.

The WHO suggests at least 9 essential indicators. The organisation states that dietary fibre and the intake of energy-dense foods are convincingly related to obesity. The intake of fatty acids (saturated fatty acids, trans fats), fish oils (fatty fish), sodium (salt), moderate alcohol consumption and consumption of fruits and vegetables are positively or negatively related to cardiovascular diseases. The intake of fruits and vegetables, preserved meat, alcohol, and salt are most likely related to some types of cancer. Obesity is associated with coronary heart disease and certain types of cancer. Free sugars are convincingly related to dental diseases (WHO, 2003). The advice of the WCRF confirms 6 of the WHO indicators and gives special attention to a higher consumption of fruits, vegetables, whole grains, and pulses (fibres) and a lower consumption of energy-dense foods (high in fats, added sugar and low in fibre), sugary drinks, salty foods, and red or processed meat. WCRF adds an indicator of good energy balance, which is also essential (obesity may result if intake exceeds physical activity).

The Dutch Institute for Health RIVM mentions 7 of the indicators mentioned by WHO and WCRF. They estimated that in addition to being overweight (energy unbalance), five nutritional factors are mostly responsible for diet-related health loss: overconsumption of saturated fats and trans fats, and underconsumption of fish, vegetables, and fruits (Kreijl et al., 2004). Being overweight in the Netherlands is responsible for 215,000 disability adjusted life years (DALYs), and the five other nutritional factors account for 245,000 DALYs. Thus, both energy balance and these five factors should be part of the score.

In general, the following interrelationships that support the choice of indicators can be noted (Kreijl et al., 2004):

- Reducing the intake of energy-dense foods (extras) is convincingly related to a lower risk of obesity.
- A higher consumption of fruits and vegetables has been proven to lower the risk of obesity and cardiovascular disease.
- A high intake of dietary fibre is associated with a lower risk of obesity.
- An increase in the consumption of fish oil is associated with a lower risk of heart disease.
- Reducing the consumption of saturated and trans fats is associated with a lower risk of coronary heart disease. The main sources of saturated fatty acids are meat, meat products, cheese, milk and fat (butter, palm oil, coconut fat).
- A lower sodium intake and increased potassium intake is associated with a lower risk of heart disease. The most important sources of sodium are meat (and meat products), cheese, and bread.
- A reduction in alcohol consumption is associated with a lower risk of heart disease and cancer. A moderate alcohol intake has a preventive effect on cardiovascular disease.
- There is a plausible but inconclusive link between the consumption of processed meat, the high consumption of red meat and cancer.

No additional direct links between meat consumption and lifestyle diseases were identified (Kreijl et al., 2004). Although moderate alcohol consumption is mentioned as a good indicator, we did not use this indicator in the present study because the alcohol consumption in diets 2–5 is assumed to be equal to the Mediterranean diet. The reduction of (red) meat consumption indicator was used to select the different diets.

The Dutch Health Council (2006) has translated and quantified the ten indicators towards a recommended intake in the Dutch population as follows (see Table 1):

- 150–200 g of vegetables (1).
- 200 g of fruits (2).
- Less than 10% of energy from saturated fat (4).
- Less than 1% of energy from trans fat (5).
- A maximum of free sugars 7 times a day (6).
- 30–40 g of fibre (7).
- A maximum of 6 g of salt (8).
- 2 portions of fish per week (approximately 37 g per day) (9).

Note that a high consumption of fish (more than 5 servings) can have negative impacts on health due to contaminants such as heavy metals (Mozaffarian and Rimm, 2006) but it is safe to eat less than 50 g per day (DGAC, 2010). For adults, the benefits of fish intake generally exceed the potential risks, unless they consume excessive amounts.

Finally:

- 2000 kcal is advised for inactive adult women to maintain energy balance (10) (Voedingscentrum, 2011).

Some reference values differ from the WHO values. The WHO has published additional recommendations for a maximum of 10% of total energy consumption from free sugars (6; the indicator free sugars is sometimes replaced by added sugars, mono plus disaccharides or frequency of sugared drinks) and 30% of energy from total fatty acids (3). Five of the ten indicators are the same as those in the Healthy Eating Index: fruits, vegetables, total fat, saturated fat, and sodium. We replaced the five others with other indicators, i.e., grains were replaced by fibre, and meat was replaced by fish. Similar to the Healthy Eating Index, the ten indicators are weighted equally (1/10) in the total score. Our scores differ in the sense that these have no maximum at the recommended level of intake. The recommended intake is the reference value of 100.

We calculated the scores based on the ten indicators and six diets (Table 2) with the following formula:

$$\begin{aligned}\text{Health score} = (&\text{g vegetables}/200 + \text{g fruits}/200 + \text{g fibre}/30\\&+ \text{g fish}/37 + 30/\text{en\% total fat}\\&+ 10/\text{en\% saturated fat} + 1/\text{en\% trans{-}fat}\\&+ 10/\text{en\% free sugars} + 6/\text{g salt}\\&+ 2000/\text{kcal energy})/10\end{aligned}$$

*Indicators and sustainability score*

'Low environmental impacts' – as part of the definition of sustainable diets – need to be quantified using different parameters. The main environmental issues related to food include climate change, fossil fuel extraction, biodiversity loss, ecosystem change, ozone layer depletion, mineral extraction, acidification, and eutrophication (Eco-Indicator 99 in Tukker et al., 2009; Goedkoop and Sprienstra, 2001). Rockström et al. (2009) quantified and ranked the main environmental issues by defining 'planetary boundaries' with respect to the following (in order of decreasing importance): loss of biodiversity, climate change, nitrogen and phosphorus cycle disruption, ozone depletion, acidification, global freshwater use and land use change (Rockström et al., 2009). For the Dutch situation, Nijdam and Wilting (2003) illustrated that food consumption is the main source of eutrophication (71%), land use (56%), freshwater use (53%), acidification by manure (40%) and global warming (30%) (Nijdam and Wilting, 2003). In view of the increasing pressures on earth systems, the macro perspective is crucial to understand the intertwined threats of the rate of biodiversity loss, disruption of the nitrogen cycle and the carbon cycle (i.e., climate change), land use change, freshwater use, and phosphate depletion, which are interlinked and amplified by animal protein conversion

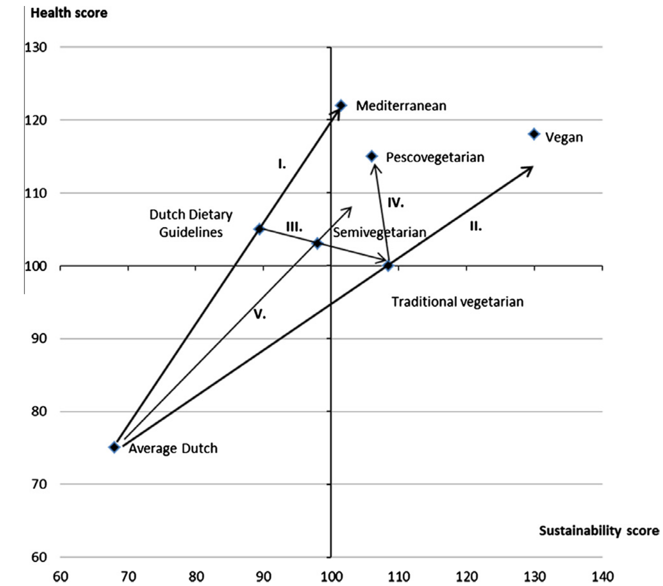


**Fig. 1.** Matrix with a comparison of the health and sustainability scores of different diets (Health score of 100 complies with WHO and Dutch guidelines; a sustainability score of 100 complies with a 20% reduction in GHG and a 44% reduction in LU). To explore both scores of the current Dutch diet, we analysed diets with a health focus (I) and animal protein reduction (II), as well as combinations of the two. The arrows illustrate the different options to improve the scores. (I) Health focus, (II) animal protein reduction, (III) dietary guidelines diet towards animal protein reduction, (IV) vegetarian diet towards health focus, (V) easiest choice for simultaneously higher health and sustainability score (semi- and pesco-vegetarian).

losses (De Boer and Aiking, 2011). Energy use and greenhouse gas emissions can be considered good proxies for this total environmental impact (Dutilh and Kramer, 2000). Land use and land use change are good proxies for loss of biodiversity (Pereira et al., 2010). Eutrophication is associated with biodiversity loss and results from intensive land use with extensive application of fertilisers (Abell et al., 2011). Eutrophication and biodiversity loss are strongly interlinked (Aiking, 2011). Agricultural land use is the main type of land use due to the absence of mountains and rocks and the high percentage of arable land in the Netherlands. In the present study, we therefore used LU and GHG emissions as indicators to quantify (in relative terms) the environmental impact of the six different diets, because together they cover at least the top 4 of the impacts identified by Rockström et al. (2009). Water use is not included as an indicator. Besides, there is a strong correlation between LU and water footprint *($p < 001$, Van Dooren and Douma, 2012 unpublished).*

In the scope of the European and worldwide reduction policies for GHG, it is relevant to also look towards our nationwide diet. The present (2013) goal for the European Commission is a reduction of at least 20% by 2020. We used the 2020 goal of a 20% GHG reduction in the food chain as a reference value, although it is a political, arbitrary choice. The present average Dutch diet is 4.09 kg $CO_2$eq/day (Fig. 2); the 2020 goal is 20% lower or 3.27 kg $CO_2$eq/day. This level was allocated a score of 100.

For LU we have no single reference value. Publications about the ecological footprint (WWF, 2012) suggest that the worldwide available biocapacity calculated in land use is 1.78 global hectares. The current land use in the Netherlands, according to the WWF, is 3.20 global hectares, which is 44% above the available capacity. We used a 44% reduction in the food chain applied for land use as a reference, a reduction from 5.34 $m^{2*}$year/day (the land use of the average Dutch diet; Fig. 3) to 2.97 $m^{2*}$year/day (A reduction in land use of 44%; $m^{2*}$year is the unit for land use). This value was indicated as 100. Therefore, the present average Dutch diet received a score of 56 (44% below the reference value). Table 3 gives an overview of the six diets scores calculated based on the results as shown in Figs. 2 and 3. The sustainability score was defined as the average of the GHG and LU score per diet. The score was calculated with the following formula:

$$\text{Sustainability score} = (\text{kg } CO_2\text{eq GHG}/3.27 + \text{m}^2 * \text{year LU}/2.97)/2$$

*Life Cycle Assessment of agriculture products*

Our calculation of the GHG emissions and LU of the most consumed products in the diets was completed using a Life Cycle

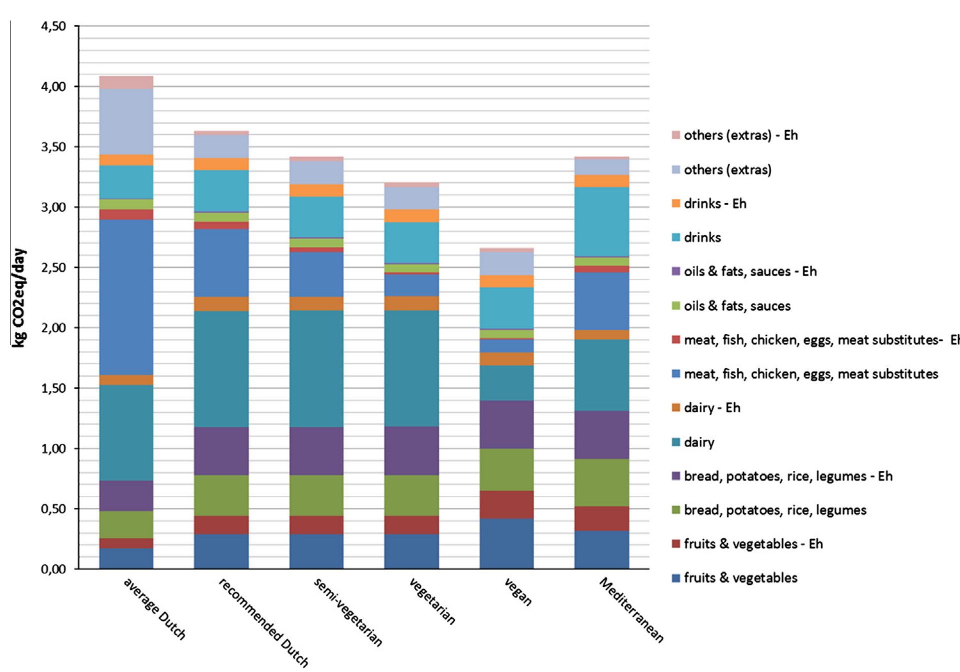


**Fig. 2.** GHG emissions per day according to the 6 diets and broken down into 7 food groups (female adults). Eh = energy use in the household phase.

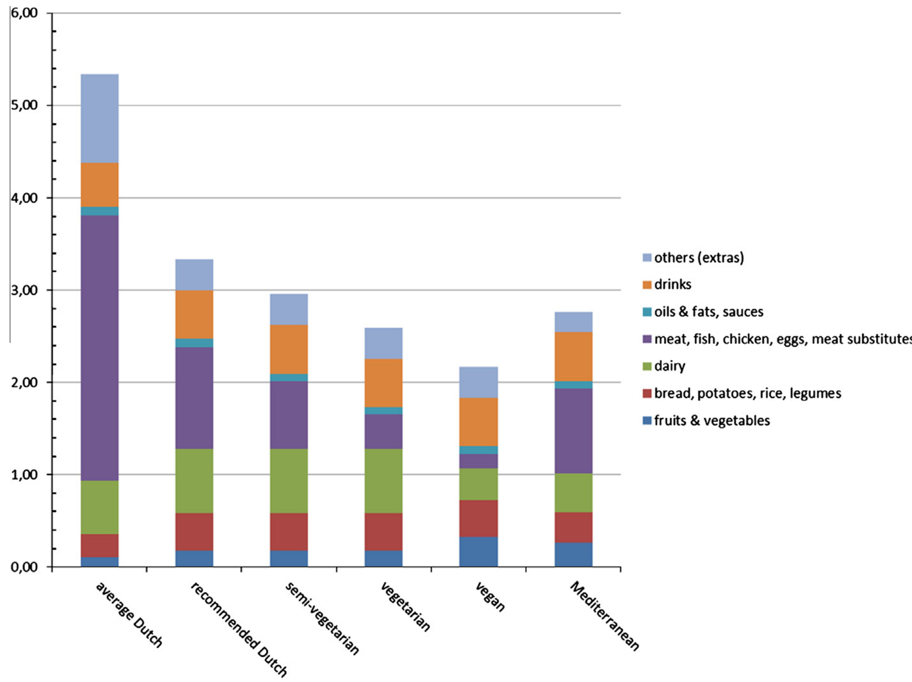


**Fig. 3.** Land use ($m^{2*}$year/day) per day according to the 6 diets and broken down into 7 food groups (female adults).

**Table 3**
Overview of six diets' health and sustainability scores.

| | Health score | GHG index | LU index | Sustainability score |
|---|---|---|---|---|
| Average Dutch | 75 | 80 | 56 | 68 |
| DDG | 105 | 90 | 89 | 90 |
| Semi-vegetarian | 103 | 96 | 100 | 98 |
| Traditional vegetarian | 100 | 102 | 115 | 109 |
| Vegan | 118 | 123 | 137 | 130 |
| Mediterranean | 122 | 96 | 107 | 102 |

Assessment (Bellows et al., 2010). LCA is a methodological framework for assessing the environmental impacts that are attributable to the life cycle of a product, such as climate change, toxicological stress on human health and ecosystems, depletion of resources, water use, land use, and noise (Blonk et al., 2011). LCA standards and handbooks currently in use include The ISO 14040/44 series (ISO, 2006a,b) and the ILCD Handbook (JRC, 2010). The details of the LCA methodology we used are described in 'The Agri-footprint method; Methodological LCA framework, assumptions and applied data, Version 1.0' (Blonk et al., 2011).

Important for LCAs on agriculture was the development of the ReCiPe method, which aggregates several other LCA impact assessment methods. The ReCiPe method (Goedkoop et al., 2009) offers a sound framework for calculating fourteen environmental impact scores. In LCAs of agricultural products, the main contributors to this end score are greenhouse gas emissions, land use, and fossil energy use (Sevenster et al., 2010). This is an important reason for selecting two of these three environmental indicators for this study. By definition, using indicators results in simplification and a certain unavoidable distortion of reality. In a recent assessment for the EU (Ernst and Young, 2010), the British PAS2050 (BSI, 2008) specification was identified as the most complete standard for calculating the carbon footprint (GHG) as a single issue LCA on global warming. We conducted the calculations according to PAS2050 with further specifications for agricultural products where necessary (Blonk et al., 2011; Kool et al., 2009). In the scope of this study, it was not possible to carry out an extensive assessment to define standard deviations for the parameters. LCA experts assume a general uncertainty of 10% to 20% in our results (Blonk et al., 2011).

## Results

### *The six diets evaluated with regards to health*

In Table 2 the health gain is calculated as a score per indicator and a total score. The average Dutch diet clearly has a low health score of 75. The DDG, semi-vegetarian, and vegetarian diets have almost the same health scores (100–105). The vegan (118) and Mediterranean diets (122) have higher overall health scores. Lower salt consumption and higher fish intake are the hardest to achieve for all diets, even for the reference diet according to the guidelines (DDG), although the salt intake of the Mediterranean diet is very close to the reference value. In the vegan and vegetarian diet, omega-3 fish oils are lacking. In conclusion, diets 2–6 all have significant health benefits in the sense of a reduction in the risk of certain lifestyle-related diseases. Diet 6, the Mediterranean diet, differs the most from the average Dutch diet.

### *The six diets evaluated with regards to GHG and LU*

The results of the six diets of female adults on greenhouse gases (GHG) and LU are shown in Figs. 2 and 3, respectively. We analysed several diet options with respect to GHG emissions and LU. The average Dutch diet has a greenhouse gas emission of 4.1 kg $CO_2$-

eq/day (score 80), and the same figure for the DDG diet is 3.6 kg $CO_2$-eq/day (score 90). This is of the same magnitude that other studies have found: 3.02 kg $CO_2$-eq/day for the US MyPlate (Venkat, 2011), 4.09 kg $CO_2$-eq/day for the average French diet (Vieux et al., 2011) and 3.0 kg $CO_2$-eq/day for the average Dutch diet (Nijdam and Wilting, 2003). This represents a substantial portion of the total emissions from human consumption, which is 11 kg $CO_2$-eq/day (Nijdam and Wilting, 2003). Our study shows that the vegetarian and vegan diet, with indicator values of 102 (vegetarian) and 130 (vegan diet), generate emissions that go beyond a 20% reduction compared to the average Dutch diet (Table 3). The Mediterranean (96) and semi-vegetarian diet (96) both are close to the 100 reference score. Therefore, we found four diets with a GHG score meeting the EU target of a 20% reduction in emissions, with the vegan diet exceeding this target (123).

The average Dutch diet has a land use of 5.34 $m^{2*}$year/day, and the largest reduction is obtained by a vegan diet (−59%, 2.17 $m^{2*}$y/d). The LU score of the vegan diet is 130 (Table 3). The diet according the Dutch dietary guidelines has an indicator value significantly below the reference defined above (score 89). The other four diets all are at or above the reference value: semi-vegetarian (100), Mediterranean (107), vegetarian (115), and vegan (137).

*Breakdown of the reductions by food group*

A change from the average Dutch diet to the recommended diet gives an 11% reduction in GHG and a 38% reduction in LU. This is a substantial decrease. Although some product groups, such as fruits and vegetables, give a small increase in impact, the reduction is entirely attributable to less meat and fewer extra products such as snacks, sweets, pastries, etc. The lower impact of the vegan and Mediterranean diets are also partly explained by a lower consumption of dairy products.

The food groups contributing most to the GHG of the Dutch diet are meat products (32%), dairy (19%), extras (13%), and drinks (7%). Preparation and storage contribute 17%. More than GHG, LU is determined by the share of meat in the diet. The top contributing food groups are meat (54%), extras (18%), dairy (11%), and drinks (9%). The contribution of drinks is due to coffee and tea consumption. Preparation and storage do not contribute to LU.

In summary, when comparing different food groups, the greatest reduction in GHG and LU can be obtained by reducing consumption of meat, dairy products, extras, and beverages (alcoholic, juices, soft drinks, coffee, and tea), in that order.

Even more concisely, to counter the total impact of diet on GHG and LU, the reduction of meat consumption is found to be the most effective option. The meat group is indeed responsible for 34% of GHG emissions (including household energy use) and 54% of LU.

Other options are decreasing food waste (7–12% of GHG emissions; usual food waste is regarded and calculated within the emissions of the food groups).

The diets have been calculated for adult women because this is the largest homogeneous population group with available data, and using this population allows for conservative effects estimations. If men were chosen as the reference group, both the differences and the gains would have been higher. This is because men eat larger quantities (25% more energy), relatively more meat, fish and eggs, more alcoholic drinks, and more extras (TNO, 1998). Consequently, the results of the women are on the conservative side, compared to men. A Finnish (Risku-Norja et al., 2008) and French study concluded that men have a much higher climate impact than women (4.7 versus 3.7 kg $CO_2$-eq) (Vieux et al., 2012). Vieux et al. (2012) also showed that for every 100 kcal decrease in consumption, GHG emissions are reduced by 275 g.

## Discussion regarding specific food groups and patterns and comparison with the findings of earlier studies

This section explores the effects of different options and directions on health and sustainability. Four product groups are responsible for 71% of GHG and 92% of LU. We discuss these four groups, including meat, dairy, extras, and drinks. These groups determine the environmental impact and the ranking of the health and sustainability scores. Thereafter, we analyse the synergy between health and sustainability.

*The effects of less animal protein*

The GHG and LU of the Dutch diet are for over 50% determined by the consumption of animal products (meat plus dairy, 51% GHG and 65% LU). Gerbens-Leenes has shown in more detail that animal products have the largest impact in the Dutch diet in terms of energy requirements (45%), land use (54%), and water (66%) (Gerbens-Leenes, 2006). The impact of animal protein products has been known for decades. Interestingly, an older Dutch study had the same outcome: 51.1% of the GHG was due to meat, meat products, fish, and dairy (Kramer et al., 1999). The food system contributes significantly to global GHG emissions. All stages in the supply chain contribute, but on average, the agricultural stage is the single largest GHG emitter, while meat and dairy products are the most GHG-intensive food types (Garnett, 2011).

We have previously calculated that the reduced consumption of meat and dairy (especially cheese) in the diet reduces the GHG and the LU of food (Blonk et al., 2008). Other studies confirm the reduction of LU through vegetarian diets (Wirsenius et al., 2010).

Other studies have also shown that plant-based diets have a lower environmental impact than diets rich in meat. A 50% meat reduction already affects the impact (Vieux et al., 2011). The primarily meat-based food system requires more energy, land, and water resources than a lacto-ovo-vegetarian diet (Pimentel and Pimentel, 2003). Assessment suggests that, on average, the environmental impact of non-vegetarian meals may be roughly a factor of 1.5–2 higher than the effect of vegetarian meals in which meat has been replaced by plant proteins (Reijnders and Soret, 2003). Baroni calculated a resource impact reduction of 38% for a vegetarian diet and 62% for a vegan diet, although the vegetarian and vegan diets result in higher energy intakes (Baroni et al., 2006). These studies show a larger reduction than we observed in our study. A smaller reduction of GHG was found in a recent British study: 22% for a vegetarian diet and 26% for a vegan diet, in comparison to the average UK diet based on supply data rather than consumption data (Berners-Lee et al., 2012). A recent study showed that a vegetarian, and semi-vegetarian diet give also a significant reduction regarding the water consumption (Vanham et al., 2013). Diets based on a reduction in animal proteins clearly improve the sustainability score is the inevitable conclusion (Fig. 1).

*Health focus: the effects of fewer extras and choices in beverages*

Eating according to DDG as part of the health focus direction (Fig. 1(I).) provides better scores for both health and sustainability indicators than eating according to the current pattern. This is not only due to a lower consumption of meat but is also due to a lower consumption of optional products in the extras category. An important outcome of this study is that extras determine 13% of GHG and 18% of LU. Extras are products with high energy content but low nutritional value and contribute significantly to the greenhouse effect of food. This is confirmed by other studies (Garnett, 2008; Tukker et al., 2006). A Swedish study calculated a contribution of 20% to GHG by drinks and sugary foods (Barrett et al., 2002).

In the Mediterranean diet, the extras group is the smallest at 200 kcal/day.

One other striking outcome of this study is the high contribution of drinks, in addition to milk. Non-alcoholic beverages are responsible for 7% of GHG and 9% of LU. In the Dutch pattern, these beverages are mainly coffee and tea. Alcoholic drinks and soft drinks also have high impacts. These are part of the extras group. Other studies have also shown a high impact of drinks (Garnett, 2008). Consumption of beverages, such as coffee and tea, contributes significantly to the LU and ecological footprint (Frey and Barrett, 2007). The most effective option in light of health, GHG and LU is to drink tap water (Gleick and Cooley, 2009). Gerbens-Leenes (2006) also showed that the growth in diets' environmental impact during the last decades is explained by growth in the consumption of beverages such as coffee, beer and wine.

This study clearly shows that there are other possibilities to reduce GHG, energy consumption and LU, such as lowering the environmental impact of beverage packaging: for example, drinking tap water instead of bottled water. Choice of drinks is part of the health focus direction.

*Reflections on how to score both on health and on sustainability*

The vegan diet has the highest score on sustainability and the second score on health. The vegetarian diet is second in sustainability but third in health. A barrier to recommending a vegan diet is the supply of some nutrients, such as vitamin B12, iron, vitamin D and calcium. Other nutrients of potential concern include EPA, and DHA (ADA, 2009; DGAC, 2010). This is to some extent also the case for vegetarians. Vegetarians' diets are healthy if attention is paid to alternative sources or fortified foods such as meat substitutes and soymilk (Millward and Garnett, 2010; Jacobs et al., 2009). The USDA therefore developed lacto-ovo-vegetarian or vegan food pattern adaptations that illustrate varied approaches to healthy eating patterns. These adaptations rely on fortified foods for some nutrients. In the vegan patterns, in particular, fortified foods provide much of the calcium and vitamin B12, and either fortified foods or supplements should be selected to provide adequate intake of these nutrients (USDA, 2010). There is also an absence of fish oils in the studied vegan and vegetarian diets (Table 1). Land plants, such as canola and linseed, contain a alternative source of omega-3 although these are not the beneficial long-chain varieties. Other potential sources include microalgae (Nichols et al., 2010). If we include a weekly portion of fatty fish or omega-3 supplements in the traditional vegetarian diet, the health score rises to 115, and the sustainability score is changed to 106 (this is called a pesco-vegetarian diet). Therefore, a small portion of fish and/or meat (semi-vegetarian) in the diet is more than adequate from a health perspective. Adding an omega-3 source turns the animal protein reduction direction toward a health focus, immediately improving the health score (Fig. 1(IV).).

A stronger argument against a vegan diet is that it is in conflict with the FAO definition of sustainable diets: it is neither nutritionally adequate, nor culturally acceptable to the general public. The provision of vitamin B12, iron, and calcium is lower than usual and requires proper planning and discipline. Poorly planned vegetarian diets may sometimes fall short of these nutrients (ADA, 2009). A shift to a vegan diet, including addition of fortified foods or supplements, seems less feasible for the general public; the gap between the average diet and a vegan diet in Fig. 1(II) is indeed the largest. This illustrates a trade-off between health and sustainability due to the role of fish and dairy in the diet.

An entirely meatless diet is not necessary and not optimal from health and environmental perspectives. To keep the environmental impact of meat at the level it was in 2005, meat consumption has to be reduced to 90 g per person per day, with a maximum of 50 g of red meat (McMichael et al., 2007; Stehfest et al., 2008). In 2050, only 25 kg of meat per person (68 g per day) and 53 kg of milk (145 ml per day) will be available per inhabitant, according to projections (Garnett, 2008). It should be noted that 68 g is available carcass weight; real consumption is approximately half of this. The optimum nutrition from the perspective of LU fits within the American nutritional guidelines. A reduction in meat consumption from 163 g per day (average USA) to 63 g per day, in combination with a limited fat intake, and an unchanged energy consumption of 2308 kcal, would result in an optimal reduction in LU (footprint) by approximately 40%. A vegan or vegetarian diet gives less reduction in LU, in fact (Peters et al., 2007). Thus, a small portion of meat in the diet is ecologically efficient. According to the present study, in the animal protein reduction choice, a full sustainability score of 100 points is reached before all meat is left out (Fig. 1(II)).

*Reflections on synergies between high health and sustainability scores*

The Mediterranean diet, as the most far-reaching health focus option, gives the most health gain as shown clearly in Section. The six diets evaluated with regards to health and Fig. 1. The sustainable score (102) is on the same order as the vegetarian diet (109), but the vegetarian diet scores lower on health (100 versus 122).

The Mediterranean diet is best known through the studies of Ancel Keys (1970, 1980), Willett et al. (1995), and Trichopoulou et al. (2005), who concluded that the menu reduces the risk of cancer, heart disease, diabetes and other conditions. This diet is rich in vegetables, fruits, grains, and unsaturated fatty acids (fish and olive oil). The fact that the Mediterranean option gives GHG savings of 16% and the same effect as cutting back meat consumption by 50% is a striking result. The consumption of a large quantity of fruits and vegetables, pulses, and some more (whole grain) cereals and a shift to vegetable oils, such as olive oil, has little effect on the climate impact. The gain is mainly in a lower consumption of dairy products, the source of animal protein (per week 2 portions of fish, 1 chicken and 1 pork or beef) and 100 kcal less extras. This diet combines the recommendations provided in Sections The effects of less animal protein, Health focus: the effects of fewer extras and choices in beverages, and Reflections on how to score both on health and on sustainability.

In 2010, an interesting study was published on this issue (Buchner et al., 2010), based on the ecological footprint as an indicator. Buchner compared the footprint with the score of preference related to health in the food pyramid. The higher a product is in the pyramid, the lower the recommended amount of consumption. Phrased differently, foods that are recommended for health reasons generally have lower environmental impacts as well. In contrast, foods with lower recommendations are those with a higher environmental impact. Although the parallel is not one hundred percent and a limited number of products were involved, this study resulted in a remarkable conclusion.

More studies have pointed to the Mediterranean diet as an example of a sustainable diet (Burlingame and Dernini, 2011). A well-balanced Italian diet also has a much lower environmental impact (−62%) than the current Italian diet based on industrial agriculture (Baroni et al., 2006). A global shift toward a Mediterranean-type or other more plant-based diets (like pesco-vegetarian) could be expected to have a more favourable impact on the environment and on health (Duchin, 2005). Although the pesco-vegetarian diet has a lower health score compared to the Mediterranean diet, it is more feasible (Fig. 1(V)). This diet also reaches a sustainability score of 100 more easily.

*Reflections on applicability in guidelines and consumer choices*

This study confirmed, in a quantitative way, the notion that there are major synergies between choosing healthier and more sustainable diets and food patterns. Such findings are relevant to consumers' choices as well as advisory bodies. We believe that an extension of the present nutritional guidelines towards more inclusive guidelines that include environmental effects and sustainability issues is not only feasible but also desirable and relatively easy because of the large overlap.

According to the outlook of the FAO, the need to consider sustainability issues of food production and consumption is urgent (FAO, 2010b). By 2050, the world's population will reach 9.1 billion, 34% higher than today. Just satisfying the expected food and feed demand will require a substantial increase in global food production of 70% by 2050. Much of the natural resource base already in use worldwide shows worrying signs of degradation. According to the Millennium Ecosystem Assessment, 15 out of 24 ecosystem services examined are already being degraded or used unsustainably (FAO, 2010b). The FAO states that governments, UN agencies, civil society, research organisations and the private sector should collaborate in the development of programme activities and policies to promote sustainable diets in order to achieve sustainable food production, processing, and consumption and to minimise environmental degradation and biodiversity loss (FAO, 2010a). Therefore, it is important to make consumers aware of the option of choosing a more sustainable diet.

A first step towards the option of this sustainable diet through a health focus is set by the new Dutch guidelines from the Health Council (2011). The Council concluded that eating a diet according to 'Guidelines for a healthy diet' is not only good for human health but also generally eco-friendly. These are the conclusions of the Health Council of the Netherlands' advisory report 'Guidelines for a healthy diet: the ecological perspective' (Health Council, 2011). The guidelines include a protein reduction-directed solution, by advising a lower consumption of meat and dairy and a re-evaluation of fish recommendations down to one portion per week. This step towards a semi-vegetarian diet is balanced in between the health focus and protein reduction (Fig. 1(V)) and within reach for the majority of consumers.

Results of this study are completely in line with the new Dutch guidelines. The results also underline three of the seven conclusions of the British Sustainable Development Commission (Reddy et al., 2009). These ecological guidelines go far beyond the first sustainable guidelines in 1986 focusing on minimal processing and packaging and on locally produced food (Gussow, 1999). No doubt, these guidelines will contribute to improved scores in health and sustainability and contribute to the possibility for consumers to choose a more healthy and sustainable diet in the near future.

One of the limitations of this study may be the focus on the Dutch situation; however, the results will be an illustrative example and the used methods easily adaptable to other countries. Although the scores used are new they are in line with international guidelines. Using more LCA data on food products and adding more indicators of sustainability, such as water use, would further improve the score. More research is needed to refine and validate the health and sustainability scores and to apply them to other countries and diets. It is also worthy to investigate the possibilities of health and sustainability scores at the level of products or products groups. Tools can be developed to support consumers in making both healthier and more sustainable choices.

## Conclusions

The quantification of health and sustainability in scores can support consumers to become aware, to compose personal diets, and to make more informed choices. This study showed that eating a recommended healthy diet (health score ⩾ 100) in compliance with the Dutch Dietary Guidelines is likely to result in a higher sustainability score. Diets with a higher health score, such as Mediterranean and pesco-vegetarian diets, also had a higher sustainability score. In other words, the high health scores of these diets are paralleled by high combined sustainability scores, as shown in Table 3 and Fig. 1. We conclude that guidelines oriented in between a health focus and animal protein reduction is the option with the optimal synergy between health and sustainability. The matrix (Fig. 1) can be considered a first step in the development of a tool to measure both sustainability and health issues of specific food patterns.

The synergy of both scores can be explained by a reduction in overall food consumption and by a reduction in the consumption of meat, dairy and extras in particular. The results of this study translated into practice mean that consumers can choose to reduce greenhouse gas emissions most effectively through:

- Reduction of meat and dairy consumption.
- Eating more plant based foods or shifting to a pesco-vegetarian diet.
- Choosing beverages carefully.
- Eating fewer extras.

There is a growing consensus about these new ecological guidelines.

Eating according to the Dutch Dietary Guidelines is healthier and more sustainable than the average Dutch diet; however, further improvements in health scores, GHG emissions, and LU are within reach. The Mediterranean diet is generally the health focus option with a high sustainability score. The vegan diet combines a high health score with the highest animal protein reduction. As a feasible compromise acceptable to the general public, a semi-vegetarian diet seems the best option for consumers to improve both scores simultaneously.

## References

Aiking, H., 2011. Future protein supply. Trends Food Sci. Technol. 22, 112–120.

Abell, J.M., Özkundakci, D., Hamilton, D.P., Miller, S.D., 2011. Relationships between land use and nitrogen and phosphorus in New Zealand lakes. Mar. Freshw. Res. 62, 162–175.

ADA, 2009. Position of the American dietetic association: vegetarian diets. J. Am. Diet. Assoc. 109, 1266–1282.

Bach-Faig, A., Berry, E.M., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., Medina, F.X., Battino, M., Belahsen, R., Miranda, G., Serra-Majem, L., 2011. Mediterranean diet pyramid today. Science and cultural updates. Publ. Health Nutr. 14, 2274–2284.

Baroni, L., Cenci, L., Tettamanti, M., Berati, M., 2006. Evaluating the environmental impact of various dietary patterns combined with different food production systems. Eur. J. Clin. Nutr. 61, 279–286.

Barrett, J., Vallack, H., Jones, A., Haq, G., 2002. A Material Flow Analysis and Ecological Footprint of York: Technical Report. Stockholm Environmental Institute, Stockholm, Sweden.

Bellows, A.C., Alcaraz, V.G., Hallman, W.K., 2010. Gender and food, a study of attitudes in the USA towards organic, local, U.S. grown, and GM-free foods. Appetite 55, 540–550.

Berners-Lee, M., Hoolohan, C., Cammack, H., Hewitt, C.N., 2012. The relative greenhouse gas impacts of realistic dietary choices. Energy Policy 43, 184–190.

Blonk, H., Kool, A., Luske, B., 2008. Environmental Effects of The Dutch Consumption of Protein Rich Products (in Dutch). Blonk Milieu Advies (Blonk Environmental Consultants), Gouda, Netherlands.

Blonk, H., Ponsioen, T., Kool, A., Marinussen, M., 2011. The Agri-Foorprint Method; Methodological LCA Framework, Assumptions and Applied Data, Version 1.0. Blonk Milieu Advies, Gouda, Netherlands.

BNF, 2007. Healthy Eating: A Whole Diet Approach. British Nutrition Foundation, London, UK.

BSI, 2008. PAS 2050:2008 Specification for The Assessment of The Life Cycle Greenhouse Gas Emissions of Goods and Services. British Standards, Carbon Trust, Defra, London, UK.

Buchner, B., Fischler, C., Fitoussi, J.-P., Monti, M., Riccardi, G., Ricordi, C., Sassoon, J., Veronesi, U., 2010. Double Pyramid: Healthy Food For People, Sustainable Food For The Planet. Barilla Center for Food & Nutrition, Milan, Italy.

Burlingame, B., Dernini, S., 2011. Sustainable diets: the Mediterranean diet as an example. Publ. Health Nutr. 14, 2285–2287.
Davies, S., 2011. Making sustainable choices easier. Nutr. Bull. 36, 454–459.
De Boer, J., Aiking, H., 2011. On the merits of plant-based proteins for global food security: marrying macro and micro perspectives. Ecol. Econ. 70, 1259–1265.
Dietary Guidelines Advisory Committee (DGAC), 2010. Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2010, to the Secretary of Agriculture and the Secretary of Health and Human Services. U.S. Department of Agriculture, Agricultural Research Service, Washington, DC.
Duchin, F., 2005. Sustainable Consumption of Food: A Framework for Analyzing Scenarios about Changes in Diets. J. Ind. Ecol. 9, 99–114.
Dutilh, C., Kramer, K.J., 2000. Energy consumption in the food chain. Ambio 29, 98–101.
Elferink, E.V., 2009. Meat, milk and eggs: analysis of the animal food environment relations. IVEM, RuG, Groningen, Netherlands.
Ernst, Young, 2010. Product Carbon Footprinting – A Study on Methodololgies and Initiatives. Ernst & Young for EU DG Environment. Brussels, Belgium.
FAO, 2010a. Biodiversity and Sustainable Diets United Against Hunger. International Scientific Symposium, FAO Headquarters, Rome.
FAO, 2010b. How to Feed the World in 2050, Rome, Italy.
Fidanza, F., Alberti, A., 2005. The Healthy Italian Mediterranean Diet Temple Food Guide. Nutr. Today 40, 71–78.
FRDO, 2011. Advice on Animal and Vegetable Proteins (in Dutch). Federale Raad voor Duurzame Ontwikkeling, Brussels, Belgium.
Frey, S., Barrett, J., 2007. Our Health, Our Environment: The Ecological Footprint of What We Eat, International Ecological Footprint Conference. Stockholm Environment Institute, Cardiff, UK.
Garnett, T., 2008. Cooking Up a Storm; Food, Greenhouse Gas Emissions and our Changing Climate. FCRN, Food Climate Research Network, Surrey, UK.
Garnett, T., 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food Policy 36, S23–S32 (Supplement 1).
Gerbens-Leenes, P.W., 2006. Natural resource use for food: land, water and energy in production and consumption systems. Thesis (90-367-2867-3) Rijksuniversiteit Groningen, Groningen, The Netherlands.
Gleick, P.H., Cooley, H.S., 2009. Energy implications of bottled water. Environ. Res. Lett. 4, 014009.
Gerlach, A., Hohfeld, L., Schamhorst, S., Schudak, A., 2009. The Sustainable Shopping Basket. German Council for Sustainable Development, Berlin, Germany.
Goedkoop, M.J., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., Van Zelm, R., 2009. ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; Report I: Characterisation. first ed., Pré Consultants, Amersfoort, Netherlands.
Goedkoop, M.J., Sprienstra, R., 2001. The Eco-indicator 99, A damage oriented method for Life Cycle Impact assessment; Methodology Report., first ed., Pré Consultants, Amersfoort, Netherlands.
Gussow, J.D., 1999. Dietary guidelines for sustainability: twelve years later. J. Nutr. Edu. 31, 194–200.
Gussow, J.D., Clancy, K., 1986. Dietary guidelines for sustainability. J. Nutr. Edu. 18, 1–5.
Hahn, A., 1988. Resolving Public Issues and Concerns through Policy Education. Cornell University, Ithaca, NY, USA.
Health Council, 2006. Guidelines for Good Nutrition 2006 (in Dutch). Gezondheidsraad, The Hague, Netherlands.
Health Council, 2011. Guidelines for a healthy diet: the ecological perspective. Gezondheidsraad, The Hague, Netherlands, pp. 92.
ISO, 2006a. ISO 14040: Environmental management – Life cycle assessment – principles and framework. International Organisation for Standardisation (ISO), Geneva, Switserland.
ISO, 2006b. ISO 14044: Environmental management – Life cycle assessment – requirements and guidelines. International Organisation for Standardisation (ISO), Geneva, Switserland.
Jacobs, D.R., Haddad, E.H., Lanou, A.J., Messina, M.J., 2009. Food, plant food, and vegetarian diets in the US dietary guidelines: conclusions of an expert panel. Am. J. Clin. Nutr. 89, 1549S–1552S.
JRC, 2010. ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance European Commission. Joint Research Centre, Institute for Environment and Sustainability, Ispra, Italy.
Kennedy, E.T., Racsa, P., Dallal, G., Lichtenstein, A.H., Goldberg, J., Jacques, P., Hyatt, R., 2008. Alternative approaches to the calculation of nutrient density. Nutr. Rev. 66, 703–709.
Kennedy, E.T., Ohls, J., Carlson, S., Fleming, K., 1995. The healthy eating index: design and applications. J. Am. Diet. Assoc. 95, 1103–1108.
Keys, A., 1970. Coronary heart disease in seven countries. Circulation 41, 1–211.
Keys, A., 1980. Seven countries: a multivariate analysis of death and coronary heart disease. Ann. Intern. Med. 93, 786–787.
Kool, A., Blonk, H., Ponsioen, T.C., Sukkel, W., Vermeer, H., de Vries, J., Hoste, R., 2009. Carbon Footprints of Convential and Organic Pork. Blonk Milieu Advies, Gouda, Netherlands.
Kramer, K.J., Moll, H.C., Nonhebel, S., Wilting, H.C., 1999. Greenhouse gas emissions related to Dutch food consumption. Energy Policy 27, 203–216.
Kreijl, C., Knaap, A., Busch, M., Havelaar, A., Kramers, P., Kromhout, D., Leeuwen, F.v., Leent-Loenen, H.v., Ocke, M., Verkley, H., 2004. Our Food Measured (in Dutch). RIVM, Bilthoven, Netherlands.
Livsmedelsverket, 2009. The National Food Administration's Environmentally Effective Food Choices. Livsmedelverket, National Food Administration Sweden, Stockholm, Sweden.
Marlow, H.J., Hayes, W.K., Soret, S., Carter, R.L., Schwab, E.R., Sabate, J., 2009. Diet and the environment: does what you eat matter? Am. J. Clin. Nutr. 89, 1699S–1703.
McMichael, A.J., Powles, J.W., Butler, C.D., Uauy, R., 2007. Food, livestock production, energy, climate change, and health. The Lancet 370, 1253–1263.
Millward, J.D., Garnett, T., 2010. Plenary lecture 3 Food and the planet: nutritional dilemmas of greenhouse gas emission reductions through reduced intakes of meat and dairy foods. Proc. Nutr. Soc. 69, 103–118.
Mozaffarian, D., Rimm, E.B., 2006. Fish intake, contaminants, and human health. JAMA 296, 1885–1899.
Nichols, P.D., Petrie, J., Singh, S., 2010. Long-chain omega-3 oils – an update on sustainable sources. Nutrients 2, 572–585.
Nijdam, D., Wilting, H., 2003. Environmental Load due to Consumption on View (in Dutch). RIVM rapport, RIVM, Bilthoven, Netherlands.
Pereira, H.M., Leadley, P.W., Proença, V., Alkemade, R., Scharlemann, J.P.W., Fernandez-Manjarrés, J.F., Araújo, M.B., Balvanera, P., Biggs, R., Cheung, W.W.L., Chini, L., Cooper, H.D., Gilman, E.L., Guénette, S., Hurtt, G.C., Huntington, H.P., Mace, G.M., Oberdorff, T., Revenga, C., Rodrigues, P., Scholes, R.J., Sumaila, U.R., Walpole, M., 2010. Scenarios for global biodiversity in the 21st Century. Science 10, 1503–1509.
Peters, C.J., Wilkins, J.L., Fick, G.W., 2007. Testing a complete-diet model for estimating the land resource requirements of food consumption and agricultural carrying capacity: The New York State example. Renew Agric. Food Syst. 22, 145–153.
Pimentel, D., Pimentel, M., 2003. Sustainability of meat-based and plant-based diets and the environment. Am. J. Clin. Nutr. 78, 660S–663S.
Prochaska, J.O., DiClemente, C.C., 1983. Stages and processes of self-change of smoking: Towards an integrative model of change. J. Concult. Clin. Psychol., 390–395.
Reddy, S., Lang, T., Dibb, S., 2009. Setting the Table, Advice to Government on Priority Elements of Sustainable Diets. Sustainable Development Commission, London, UK.
Reijnders, L., Soret, S., 2003. Quantification of the environmental impact of different dietary protein choices. Am. J. Clin. Nutr. 78, 664S–668S.
Risku-Norja, H., Hietala, R., Virtanen, H., Ketomäki, H., Helenius, J., 2008. Localisation of primary food production in Finland: production potential and environmental impacts of food consumption patterns. Agric. Food Sci. 17, 127–145.
Risku-Norja, H., Kurppa, S., Helenius, J., 2009. Dietary choices and greenhouse gas emissions – assessment of impact of vegetarian and organic options at national scale. Progress Ind. Ecol. Int. J. 6, 340–354.
Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., 2009. A safe operating space for humanity. Nature 461, 472–475.
Sevenster, M.N., Blonk, H., van der Flier, S., 2010. Milieuanalyses Voedsel en Voedselverliezen. Netherlands, CE, Blonk Milieu Advies, Delft.
Simopoulos, A.P., Faergeman, O., Bourne, P.G., 2011. Action plan for a healthy agriculture, healthy nutrition, healthy people. J. Nutrigenet. Nutrigen. 4, 65–68.
Steering Group, 2010. Food for Tomorrow. Proposal for Finland's National Food Strategy, Minister of Agriculture and Forestry, Helsinki, Finland.
Stehfest, E., Bouwman, A.F., van Vuuren, D.P., den Elzen, M.G.J., Eickhout, B., Jeuken, M., van Oorschot, M., Kabat, P., 2008. Meat Consumption And Climate Policy (in Dutch). MNP, Bilthoven, Netherlands.
Stehfest, E., Bouwman, L., van Vuuren, D., den Elzen, M., Eickhout, B., Kabat, P., 2009. Climate benefits of changing diet. Climatic Change 95, 83–102.
Schwinghammer, S.A., 2013. This was all very interesting, but how can we use it? A practitioner's guide to sustainable behavior. In: Trijp, H.C.M.v. (Ed.), Encouraging Sustainable Behavior; Psychology and the Environment. Psychology Press, London, UK.
TNO, 1998. Food Consumption Survey 3 (in Dutch), 1997–1998. TNO/Voedingscentrum, Zeist, Netherlands.
Trichopoulou, A., Orfanos, P., Norat, T., Bueno-de-Mesquita, B., Ocke, M.C., Peeters, P.H., van der Schouw, Y.T., Boeing, H., Hoffmann, K., Boffetta, P., Nagel, G., Masala, G., Krogh, V., Panico, S., Tumino, R., Vineis, P., Bamia, C., Naska, A., Benetou, V., Ferrari, P., Slimani, N., Pera, G., Martinez-Garcia, C., Navarro, C., Rodriguez-Barranco, M., Dorronsoro, M., Spencer, E.A., Key, T.J., Bingham, S., Khaw, K.-T., Kesse, E., Clavel-Chapelon, F., Boutron-Ruault, M.-C., Berglund, G., Wirfalt, E., Hallmans, G., Johansson, I., Tjonneland, A., Olsen, A., Overvad, K., Hundborg, H.H., Riboli, E., Trichopoulos, D., 2005. Modified Mediterranean diet and survival: EPIC-elderly prospective cohort study. BMJ 330, 991–997.
Tukker, A., Bausch-Goldbohm, S., Verheijden, M., De Koning, A., 2009. Environmental impacts of diet changes in the EU. Joint Research Centre European Commission, Seville.
Tukker, A., Huppes, G., Guinée, J., Heijungs, R., de Koning, A., van Oers, L., Suh, S., Geerken, T., Van Holderbeke, M., Jansen, B., Nielsen, P., 2006. Environmental Impact of Products (EIPRO). IPTS/ESTO project, European Commission.
USDA, 2010. Dietary Guidelines for Americans. USDA, the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, Washington DC, USA.

Vanham, D., Mekkonen, M.M., Hoekstra, A.Y., 2013. The water footprint of the EU for different diets. Ecol. Ind. 32, 1–8.

Venkat, K., 2011. MyPlate: An analysis of climate change impact, in: CleanMetrics (Ed.), Technical Brief, Portland, Oregon, USA.

Vieux, F., Darmon, N., Touazi, D.L.G.S., 2011. Food Consumption and Greenhouse Gas Emissions: Changing Food Consumption Patterns or Consuming Less? FENS, Madrid.

Vieux, F., Darmon, N., Touazi, D., Soler, L.G., 2012. Greenhouse gas emissions of self-selected individual diets in France: changing the diet structure or consuming less? Ecol. Econ. 75, 91–101.

Voedingscentrum, 2011. Guidelines for Food Choices (in Dutch). Voedingscentrum, The Hague, Netherlands.

Vringer, K., Benders, R., Wilting, H., Brink, C., Drissen, E., Nijdam, D., Hoogervorst, N., 2010. A hybrid multi-region method (HMR) for assessing the environmental impact of private consumption. Ecol. Econ. 69, 2510–2516.

Weinstein, N.D., Rothman, A.J., Sutton, S.R., 1998. Stage theories of health behavior: Conceptual and methodological issues. Health Psychol., 290–299.

WHO, 2003. Diet, Nutrition And The Prevention Of Chronic Diseases, WHO Technical Report Series. WHO, Geneva, Switserland.

Willett, W., Sacks, F., Trichopoulou, A., Drescher, G., Ferro-Luzzi, A., Helsing, E., Trichopoulos, D., 1995. Mediterranean diet pyramid: a cultural model for healthy eating. Am. J. Clin. Nutr. 61, 1402S–1406S.

Willett, W.C., 2001. Eat, Drink, and Be Healthy: The Harvard Medical School Guide to Healthy Eating. Hardard University, Harvard, USA.

Wirsenius, S., Azar, C., Berndes, G., 2010. How much land is needed for global food production under scenarios of dietary changes and livestock productivity increases in 2030? Agric. Syst. 103, 621–638.

WWF, 2012. Living Planet Report 2012, in: WWF (Ed.). WWF, Gland, Switzerland.